GREENING AT THE SEAMS

by Zoë Hoyle

Chris Barton grew up in Kentucky, where mountaintop coal mining has definitely made its mark. Surface-mined land there has been compared to the surface of the moon; unlike the moon, there is water on the land, but it's usually been polluted by the acid drainage that forms when pyrite, the sulfide mineral found in coal seams, is exposed to air and water. Once pyrite is disturbed, the resulting acid drainage, which carries harmful metals and acidifies streamwater, can last for thousands of years. In the United States alone, some 12,000 miles of streams and 180,000 acres of lakes and reservoirs are impacted.

Acid drainage is not just a mining problem, but can occur anywhere pyrite-enriched coal or its byproducts are stored. At the **Savannah River Site** (the Site) near Aiken, SC, a million tons of fly ash and coal rejects—byproducts of electric power generation—were dumped into an unlined earthen basin from the early 1950s until the mid-1990s. Located less than half a mile from the Savannah River and just a few hundred feet from a nearby wetland forest, the 18-acre basin was not protected from rainfall; over the years the wastes exposed to rain and air formed an acidic plume that polluted nearby ground water and wetlands.

How Can Trees Grow in Acid?

Barton first came to the Site as a postdoctoral student working for the SRS **Center for Wetlands Research** on the Carolina bays restoration

Acid drainage forms when pyrite, the sulfide mineral found in coal seams, is exposed to air and water. *(Photo by Chuck Meyers, USDI Office of Surface Mining)* project (see "Restoring Depressional Wetlands" on page 25). Later hired by the center as a forest hydrologist, he took on additional projects, including the tritium phytoremediation study on the Site. Even though he had plenty to do, he found himself drawn to the familiar wasteland of the coal ash basin.

"Site managers were faced with a costly cleanup," says Barton. "Digging up the million tons of contaminated soil in the basin and shipping it off for burial somewhere else would cost millions of dollars. The other alternative, building an impermeable surface over the 18-acre basin, was also very expensive."

Site managers saw another opportunity to test whether phytoremediation—using trees to pump and treat water—could play a part in cleaning up a waste problem common to every place that's been industrialized or electrified. It just so happened that Barton had worked on a minesite as part of his graduate studies.

Barton got involved in a plan SRS scientist **Don Marx** (since retired) and the Site cooperators came up with to reduce acid drainage by covering the basin with a mature closed-canopy pine forest. Most of the rainwater falling on the basin would be taken up by the trees and released through evapotranspiration, while tree roots would stabilize the soil and keep it from eroding and transporting waste. With cooperators from the **University of Georgia**, Barton did extensive studies to establish the geochemistry of the waste site, and drainage under a variety of conditions. Their findings confirmed that the forest remediation plan should work. The next step was to figure out how to grow a pine forest on soil turned acidic by coal waste.

"The basin was actually worse than the minelands I had worked on," says Barton. "The soil had a pH of 1.0, roughly that of battery acid. Most plant physiologists will tell you that trees won't grow in soil with a pH less than 3.0. There was no vegetation, just some clumps of sedge and grass at the edge. How were we going to get trees to grow there?"

The logical step would be to apply some sort of dry cover—a layer of soil, compost, or other organic material—that would change the acidity of the soil to allow tree growth. The researchers decided to study different dry covers as a second component of phytoremediation. The ideal ground cover would both slow the movement of water and encourage bacterial activity, reducing the oxygen and water available to transform pyrite in the coal waste into acid drainage.

In 1999, the cooperators established a 4-acre study on the basin to test how well different surface and subsurface treatments improved the survivability of trees on the toxic site. They applied techniques developed earlier by Marx using the natural symbiosis between roots and soil microbes to help trees to survive in the harsh environment. In 2001, the research group planted loblolly and Virginia pines on the experimental plots, choosing these trees because of their longer growing season and past performance on acidic minesites.

"We ripped the soil and put a lot of manure on the basin plots," says Barton. "Over time, the pines on the basin grew faster than trees on the native Coastal Plain soil, which tends to be nutrient poor. The important thing is that we found relatively inexpensive treatments that allowed us to grow trees on a very acidic site for phytoremediation purposes."

New Forests on Mined Slopes

Now assistant professor in forest hydrology at the **University of Kentucky** in Lexington, Barton is still growing trees on coal waste, but on a much larger scale. Over the last 4 years, he and a multitude of cooperators have planted nearly 2 million trees on over 2,500 acres reclaimed from surface mining. Again, it's all about how you prepare the surface.

As the least expensive way to get coal out of the ground, mountaintop removal has been the method of choice for the past 20 years. To get to the coal, operators first remove all the vegetation and topsoil from the site, taking out layers of rock and soil until they hit a coal seam. Traditionally, they dump what they take out—the spoil—into nearby hollows, where it is graded and compacted and then replanted to meet Federal requirements for postmine use.

But trees won't grow well in the soil compacted by grading and contouring. Operators were failing in their requirements to restore trees to an area that had been 95 percent forest before mining. In many places, reclamation meant big grassy patches on steep slopes bisected by eroded drainage ditches running acid-rusted water. Everyone knew it wasn't good enough. Local water supplies were still polluted with iron, sulfate, and manganese. Some streams were literally covered up by spoils; erosion was pushing huge sediment loads into others.

With funding from the Forest Service and others, the University of Kentucky began a mineland reforestation research project to develop better techniques to replant trees, and to test how well forests could clean up water polluted by acid drainage. The change in approach they came up with was simple, but had to be proven effective before operators and regulators would adopt it.

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"The Surface Mining and Control and Reclamation Act of 1977 required operators to return the site to as close to the original contour as possible. To achieve this, they were grading to the point where the land was reduced to a parking lot," says Barton. "We persuaded them to just leave the spoils on the site, and to minimize grading."

Barton and partners planted millions of hardwood, poplar, and conifer seedlings on three sites in eastern Kentucky where the spoil had been dumped loosely, using three compacted sites for comparison. "The difference between the two types of sites was immediately apparent," says Barton. "Forests grew quickly on the loose rubble, while the other sites were barely able to maintain a few trees. We are now seeing over 80 percent success in replanting forests on minelands, as opposed to the 20 percent operators were getting before. It's also much more economical, saving operators up to $2,000 an acre."

It's More Than Growing Trees

"We're not just growing trees on mineland, but trying to restore the functions of the forest, its ability to reduce flooding, erosion, and sedimentation, and improve degraded water quality," says Barton. "We constantly monitor water from rainfall, runoff, and infiltration on the research sites. We're seeing a definite improvement in water quality as trees grow older and forests naturalize."

So, how did his research with SRS at the Site inform the work Barton does now?

"At the Site, we had to build partnerships to work within regulations from several government agencies, and to coordinate research," says Barton. "There were a lot of hoops to jump through before we got to plant the first tree there. The experience was invaluable to my present situation, which involves working with even more partners from Federal, State, and local government, the coal mining industry, environmental groups, educational institutions, and civic groups."

"How much time do I spend working with people? Probably around 80 percent, but for me, it's time well spent. What we've learned is applicable to almost any contaminated land; it's a matter of applying the chemistry and physics—and then working with partners to get the trees in the ground."

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How to Reclaim Coal-Mined Land to Forest

Formed in 2003, the **Appalachian Regional Reforestation Initiative** (ARRI) is a coalition of groups, including citizens, industry, and government (including the Forest Service), dedicated to restoring forests on coal-mined lands in the Eastern United States.

ARRI advocates a five-step forestry reclamation approach:

1. Create a suitable rooting medium no less than 4 feet deep and made up of topsoil, weathered sandstone, and/or the best available material.

2. Loosely grade the topsoil or topsoil substitute to create a noncompacted growth medium.

3. Use ground covers that are compatible with growing trees.

4. Plant two types of trees—early successional species for wildlife and soil stability, and commercially valuable crop trees.

5. Use proper tree planting techniques.

The specifics for each of these steps are available from the ARRI Web site under Forest Reclamation Advisories or at ***arri.osmre.gov/PDFs/FRA_No.2.pdf***.

Funded by the Forest Service, **Chris Barton**, assistant professor of forest hydrology at the **University of Kentucky**, made a 30-minute video explaining the process. You can watch it as streaming video on the **Southern Regional Extension Forestry** Web site at ***sref.info/video/reclaiming*** or you can order the DVD through the New Products Section (see page 42).

For more information:

ARRI: ***arri.osmre.gov/***

Thousands of native hardwoods have been replanted on mine reclamation sites in the past decade. *(Photo by Chuck Meyers, USDI Office of Surface Mining)*